35 U.S.C. 102(b)

The Applicants respectfully submit that the prior art of Taig and the invention encompassed by the present Claims 1, 2 and 9 of this application are fundamentally different in structure and thus in their resultant mechanical effects.

To anticipate a claim under 35 U.S.C. § 102, *a single* source must contain *all* of the elements of the claim. *Lewmar Marine Inc. v. Barient, Inc.*, 827 F.2d 744, 747, 3 U.S.P.Q.2d 1766, 1768 (Fed. Cir. 1987), *cert. denied*, 484 U.S. 1007 (1988). Also, a claim is anticipated, and therefore invalid under 35 U.S.C. § 102, if each claimed element is found in a single prior art reference. *Scripps Clinic & Research Foundation v. Genentech, Inc.*, 927 F.2d 1565, 1576 (Fed. Cir. 1991); *Carella v. Starlight Archery and Pro Line Co.*, 804 F.2d 135, 138 (Fed. Cir. 1986). There must be *no difference* between the claimed invention and the reference disclosure, as viewed by an ordinary artisan. *Scripps Clinic & Research Foundation v. Genentech, Inc.*, 927 F.2d at 1576.

In response to the first Office Action, Claim 1 was amended to include the recitation of a piezoresistive sensor *responsive as a cantilever beam*. With regard to the issue of the cantilever beam, the Examiner states, in this Office Action, that:

> "This function is taught by Taig. Clearly, one end of the beam will move with respect to the other end when the shaft is subject to torsional forces."

The Applicants believe that this is incorrect and that Taig does *not* teach a cantilever beam, nor a sensor that could possibly be *responsive* as a cantilever beam as required in Claim 1. The sensor in Taig is shown in Figure 2. Torsional member 20 fits into the opposing slots 100 and thus straddles axis 82 and input member 16. A tab portion 77 of torsional member 20 engages slot 64 in output member 18. In Figure 2 the Examiner's attention is directed to torsion member 20 which "is elongated, and flat with a central portion 66 of reduced lateral dimension." (*Col. 3, lines 45 – 47*). This central portion, having a reduced lateral dimension, defines an area parallel to the axis 82 and located between the tabs designated by the reference numerals 70 and 74. This area might best be referred to as a "void area" because there is in fact nothing there. This fact

is important and will be addressed in a moment. Furthermore, "A strain sensitive element such as a strain gauge 94 is fixedly secured to one of the surfaces of the torsion member in conventional manner." (*Col. 4, lines 7 – 9*). Also as seen in Figure 2, the strain gauge 94, which is the sensing element in Taig, is situated over the *central portion* 66 of the torsion member 20 and thus also *straddles* axis 82. This fact bears directly upon the nature of the response of the strain gauge 94 to an applied torque.

The nature of the sensor in Taig is such that, upon the application of a torque to the steering column, i.e., to the cylindrical input member 16, there will be a slight rotation of input member 16 with respect to output member 18 about the axis 82. As a consequence, torsional member 20, which is positioned within slot 100 and symmetric about axis 82, will twist about axis 82. In order to gain a better visualization of the twisting suffered by torsional member 20 reference is made to Figure 6-3(d) of *Mechanics of Materials* by W. Riley, L. Sturges and D. Morris; John Wiley & Sons, 1999 (a copy of pages 272 – 275 thereof is attached for the Examiner's ready reference). The twisting of torsional member 20 is as shown in Figure 6-3(d) of *Mechanics of Materials.*

Returning now to the so called "void area," upon assembly of the arrangement shown in Figure 2 of Taig, this "void area" is located coincident with the periphery of the shaft that makes up the input member 16. However, this "void area" is *just* that area, or location, in which the sensor of the present application is in fact found. This is seen in Figures 14A – 14D of the application as filed. Thus, even if tabs 70 and 74 of Taig are displaced with respect to one another in response to an applied torque, as the Examiner seems to be saying in the above quote, there is no material between these tabs. In other words, there is simply nothing in this "void area" to *act* as a sensor. Thus, Taig is missing an element of Claim 1, namely a piezoresistive *sensor* positioned within and along the length of a slot which is parallel to the axis of a shaft and located at a single peripheral location about the surface of the shaft.

In order to more fully grasp the distinction between the nature of the sensor in Taig and that of the present application, it will be instructive to also examine the stresses that are set up in the torsional plate 20 of Taig vs. the stresses found in the sensor 120 of the present application. The stresses set up in the torsional plate 20 of Taig as a result of the torsional loading, are at an angle with respect to the axis 82. This follows from the

twisting shown in Figure 6-3(d) of *Mechanics of Materials*. In stark contrast, the stresses that result from the loading applied to the sensor of the present application are parallel to the axis of the beam, e.g. they are compressive on one side of the beam and tensile on the opposite side. In the cantilever beam of the present application, one end of the beam moves with respect to the other as it is subject to a load as shown in Figure 4 of the application. The applied load is perpendicular to the length of the beam. There is absolutely *no* torsional loading of the sensor.

As noted above, the strain gauge 94 in Taig, is in fact situated over the *central portion* 66 of the torsion member 20 and thus also *straddles* axis 82. The torsion member 20 *twists* about axis 82, i.e. it is a member under *torsion*. Because of the fact that the strain sensor 94 is located along the axis 82, and due to the nature of the stresses set up in the torsional plate 20, the strain sensor 94 would need to be set at an angle with respect to the axis 82; much as the conventional manner in the strain sensor shown in the U. S. patent to H. Brier (2,754,465). However, these sensors, and thus the sensor 94 of Taig, do not respond as cantilever beams.

Thus, it must be seen that the sensor 94 in Taig is neither responding as a cantilever beam as required by Claim 1, nor is it positioned within and along the length of a slot which is parallel to the axis of a shaft and located at a single peripheral location about the surface of the shaft, also as required by Claim 1.

Thus, based upon the foregoing remarks, the Applicants respectfully submit that Claim 1 as amended in the response to the first Office Action, clearly distinguishes over Taig and therefore stands in condition for allowance. Claims 2 and 9 which depend directly from Claim 1 are therefore also allowable for at least the same reasons as set forth with regard to Claim 1.

35 U.S.C. 103(a)

For an obviousness rejection to be proper, the Examiner must meet the burden of establishing a *prima facie* case of obviousness. *In re Fine*, U.S.P.Q.2d 1596, 1598 (Fed. Cir. 1988). The Examiner must meet the burden of establishing that *all* elements of the invention are disclosed in the prior art; that the prior art relied upon, coupled with

knowledge generally available in the art at the time of the invention, must contain some suggestion or incentive that would have motivated the skilled artisan to modify a reference or combine references; and that the proposed modification of the prior art must have had a reasonable expectation of success, determined from the vantage point of the skilled artisan at the time the invention was made. *In re Fine*, 5 U.S.P.Q.2d 1596, 1598 (Fed. Cir. 1988); *In re Wilson*, 165 U.S.P.Q. 494, 496 (C.C.P.A. 1970); *Amgen v. Chugai Pharmaceuticals Co.*, 927 U.S.P.Q.2d, 1016, 1023 (Fed. Cir. 1996). Moreover, the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990).

The Applicants respectfully submit that there is no combination of Taig, Brosh and Buhl that teaches, nor even suggests, a piezoresistive sensor *responsive as a cantilever beam*; nor is there any combination of Taig, Brosh and Buhl that teaches, or even suggests a piezoresistive sensor *positioned within and along the length of a slot which is parallel to the axis of a shaft and located at a single peripheral location about the surface of the shaft*, both of which are required by Claims 1 and 3.

In fact, Taig teaches *away* from the invention encompassed by Claim 1 by virtue of the torsion member 20 being "elongated, and flat with a central portion 66 of reduced lateral dimension", i.e., the so called "void area." (*Col. 3, lines 45 – 47*). The present application in fact fills the technological vacuum of the "void area" explicitly *created* by, and certainly not addressed by, Taig; nor for that matter Brosh or Buhl.

Thus, the Examiner has not meet the burden of establishing that *all* elements of the invention are disclosed in the prior art and has therefore not met the burden of establishing a *prima facie* case of obviousness with respect to Claim 3, which depends from Claim 1. Claims 4 - 8 which depend variously from Claim 3 are therefore also allowable for at least the same reasons as set forth with regard to Claim 3.

Conclusion

Thus, in view of the foregoing remarks, the Applicants respectfully submit that Claim 1 is clearly distinguished over Taig and is therefore allowable. Claims 2 and 9

which depend variously from Claim 1, are therefore allowable for at least the same reasons. Notification to this effect is respectfully requested.

The Applicants also submit that a *prima facie* case of obviousness has not been established with regard to Claim 1, nor for Claim 3, depending from Claim 1. Claim 3 is therefore allowable. Claims 4 – 8, which depend variously from Claim 3, also are allowable for at least the same reasons. Notification to this effect is respectfully requested.

If there are any additional charges with respect to this response or otherwise, please charge them to Deposit Account No. 06-1130 maintained by applicant's attorney.

Respectfully submitted,
SCHROEDER, T. et al

CANTOR COLBURN LLP
Applicant's Attorneys

By: George J. Lyman

George J. Lyman
Registration No. 44,884
Customer No. 23413

Date: January 3, 2002
Address: 55 Griffin Road So.
Bloomfield, CT 06002
Telephone: (860) 286-2929

Chapter 6
Torsional Loading of Shafts

From: Mechanics Of Materials
By W. Riley, L. Sturges and D. Morris
John Wiley & Sons, 1999

6-1 INTRODUCTION

The problem of transmitting a torque (a couple) from one plane to a parallel plane is frequently encountered in the design of machinery. The simplest device for accomplishing this function is a circular shaft such as that connecting an electric motor with a pump, compressor, or other machine. A modified free-body diagram (the weight and bearing reactions are not shown because they contribute no useful information to the torsion problem) of a shaft used to transmit a torque from a driving motor A to a coupling B is shown in Fig. 6-1. The resultant of the electromagnetic forces applied to armature A of the motor is a couple resisted by the resultant of the bolt forces (another couple) acting on the flange coupling B. The circular shaft transmits the torque from the armature to the coupling. Typical torsion problems involve determinations of significant stresses in and deformations of shafts.

A segment of the shaft between transverse planes a–a and b–b of Fig. 6-1 will be studied. The complicated stress distributions at the locations of the torque-applying devices are beyond the scope of this elementary treatment of the torsion problem. A free-body diagram of the segment of the shaft between sections a–a and b–b is shown in Fig. 6-2 with the torque applied by the armature indicated on the left end as T. The resisting torque T_r at the right end of the segment is the resultant of the moment of the differential forces dF acting on the transverse plane b–b. The force dF is equal to $\tau_\rho \, dA$ where τ_ρ is the shearing stress on the transverse plane at a distance ρ from the center of the shaft and dA is a

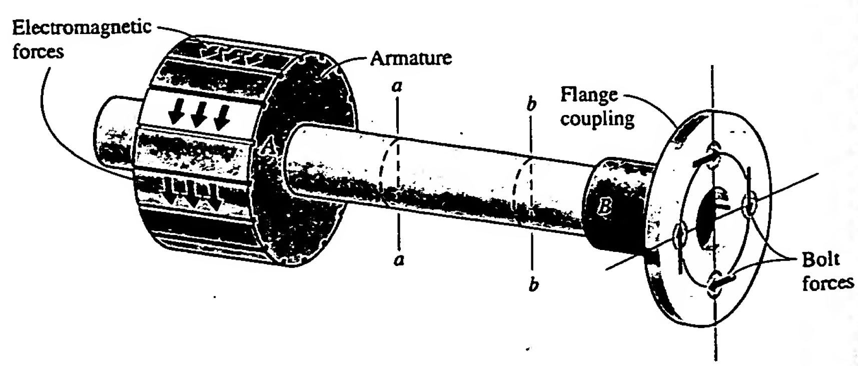

Figure 6-1

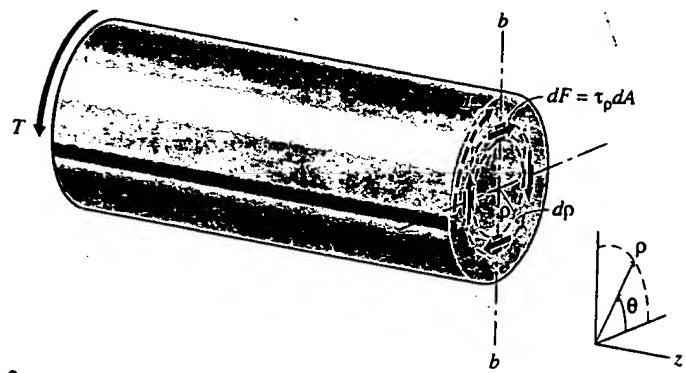

Figure 6-2

differential area. For circular sections, the shearing stress on any transverse plane is always perpendicular to the radius to the point. If the shaft is in equilibrium, a summation of moments about the axis of the shaft indicates that

$$T = T_r = \int_{\text{area}} \rho \, dF = \int_{\text{area}} \rho \, \tau_\rho \, dA \qquad (6\text{-}1)$$

The law of variation of the shearing stress on the transverse plane (τ as a function of radial position ρ) must be known before the integral of Eq. 6-1 can be evaluated. Thus, the problem of determining the relationship between torque and shearing stress is statically indeterminate. Recalling the procedures developed in Chapter 5, the solution of a statically indeterminate problem requires the use of the equation of equilibrium (Eq. 6-1 for torsion), an analysis of deformation, and the relationship between stress and strain.

In 1784 C. A. Coulomb, a French engineer, developed (experimentally) a relationship between applied torque and angle of twist for circular bars.[1] In a paper published in 1820,[1] A. Duleau, another French engineer, derived the same relationship analytically by making the assumption that a plane section before twisting remains plane after twisting and a diameter remains straight. Visual examination of twisted models indicates that these assumptions are correct for circular sections either solid or hollow (provided the hollow section is circular and symmetrical with respect to the axis of the shaft), but incorrect for any other shape. Compare, for example, the distortions of rubber models with circular and rectangular cross sections shown in Fig. 6-3. Figure 6-3*b* shows the circular shaft after loading, and illustrates that plane sections remain plane. For the rectangular shaft, plane sections before loading (Fig. 6-3*c*) become warped after loading (Fig. 6-3*d*).

6-2 TORSIONAL SHEARING STRAIN

If a plane transverse cross section of a circular shaft before twisting remains plane after twisting and a diameter of the section remains straight, the distortion of the shaft of Fig. 6-2 will be as indicated in Fig. 6-4*a*, where points B and D on a common radius in a plane move to points B' and D' in the same plane and still on the same radius. The angle θ is called the *angle of twist*. The surface ABB'

[1]From *History of Strength of Materials*, S. P. Timoshenko, McGraw-Hill, New York, 1953.

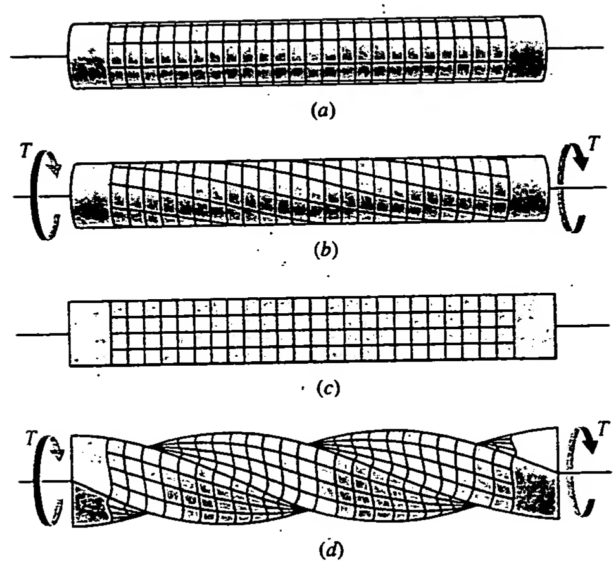

Figure 6-3

of Fig. 6-4*a* is shown in plan view in Fig. 6-4*b*, in which a differential element of the material at B (Fig. 6-4*c*) is distorted at B' due to shearing stress (Fig. 6-4*d*). Clearly, the angle ϕ of Fig. 6-4*b* is the same as the shearing strain γ_c of Fig. 6-4*d*. Similar figures could be drawn for the surface EDD'. It is recommended that the reader review the concept of shearing strain in Section 3-2.

At this point the assumption is made that all longitudinal elements (AB, ED, etc.) have the same length L (which limits the results to straight shafts of constant diameter). From Fig. 6-4, the shearing strain γ_ρ at a distance ρ from the

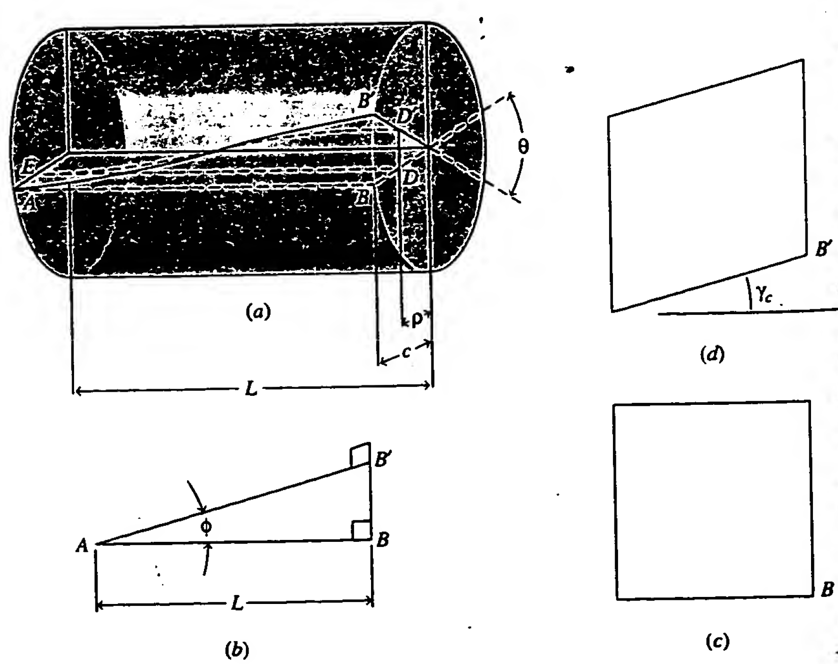

Figure 6-4

center of the shaft and γ_c at the surface of the shaft ($\rho = c$) are related to the angle of twist θ by

$$\tan \gamma_c = \frac{BB'}{AB} = \frac{c\theta}{L}$$

and

$$\tan \gamma_\rho = \frac{DD'}{ED} = \frac{\rho\theta}{L}$$

or, if the strain is small ($\tan \gamma \cong \sin \gamma \cong \gamma$, γ in radians),

$$\gamma_c = \frac{c\theta}{L} \tag{6-2a}$$

and

$$\gamma_\rho = \frac{\rho\theta}{L} \tag{6-2b}$$

Combining Eqs. 6-2a and 6-2b gives

$$\theta = \frac{\gamma_c L}{c} = \frac{\gamma_\rho L}{\rho}$$

which indicates that the shearing strain

$$\gamma_\rho = \frac{\gamma_c}{c}\rho \tag{6-3}$$

is zero at the center of the shaft and increases linearly with respect to the distance ρ from the axis of the shaft. Equation 6-3 is the result of the deformation analysis of a circular shaft subjected to torsional loading. This equation can be combined with Eq. 6-1 once the relationship between shearing stress τ and shearing strain γ is known.

Up to this point, no assumptions have been made about the relationship between stress and strain or about the type of material of which the shaft is made. Therefore, Eq. 6-3 is valid for elastic or inelastic action and for homogeneous or heterogeneous materials, provided the strains are not too large ($\tan \gamma \cong \gamma$). Problems in this book will be assumed to satisfy this requirement.

6-3 TORSIONAL SHEARING STRESS—THE ELASTIC TORSION FORMULA

If the assumption is now made that Hooke's law applies (the accompanying limitation is that the stresses must be below the proportional limit of the material), the shearing stress τ is related to the shearing strain γ by the expression $\tau = G\gamma$ (Eq. 4-1c). Then, multiplying Eq. 6-3 by the shear modulus (modulus of rigidity) G gives

$$\tau_\rho = \frac{\tau_c}{c}\rho \tag{6-4}$$

When Eq. 6-4 is substituted into Eq. 6-1, the result is

$$T = T_r = \frac{\tau_c}{c}\int \rho^2\,dA = \frac{\tau_\rho}{\rho}\int \rho^2\,dA \tag{a}$$